the critic should have nearly as much local knowledge as the author, and we pretend to none. To some though not to a great extent the besetting sin of nearly all "Faunists" is evident, and that is the tendency to exalt the importance of the capture of stray individuals, this especially among birds. The occurrence of these wanderers is undoubtedly worth recording; but that a zoologist should claim consideration for Cumberland because a *Saxicola isabellina* was shot there, or for Furness because a *Pelagodroma marina* was washed up on Walney, is an indication that he takes rather a narrow view of things—though we are bound to admit that Mr. Macpherson at the same time descants on the merits of the Wheatear as a characteristic Lakeland bird; and, especially as befits one by descent "servile to *Skyey* influences", laments the almost complete absence from the Lakeland seas of the Manx Puffin, due no doubt to its extirpation in the neighbouring island, or its Calf, that gives it an English epithet nowadays inappropriate. Indeed there is no fault to find with our author in his sympathy for the *true* denizens of his district, and the highest praise is due to him for the labour he has exercised, of which almost every page bears witness, in telling their story. To wind up we must add, what perhaps we ought to have said before, that for the purpose of this work "Lakeland" consists of the counties of Cumberland and Westmorland, together with that part of Lancashire known as Lancashire Over-Sands, being identical, the Isle of Man excepted, with the "twelfth Province" of Mr. Watson's *Cybele Britannica*; but the want of a map of the entire district is a grievous drawback, for which even the dozen or more excellent etchings, showing as many places of interest, do not wholly make amends.

THE EVOLUTION OF DOUBLE STARS.

Die Entwickelung der Doppelstern-Systeme. Von T. J. J. See. 60 pp. (Berlin: R. Friedländer und Sohn, 1893.)

THE essay which we review is a dissertation for the doctorate of philosophy of Berlin, and the author, Mr. See, is an American, although he writes in German.

The component stars in double systems appear to be usually of comparable magnitudes, and are found to move in highly eccentric orbits. This case the author holds to be the normal one, whilst the solar system, with its one preponderant mass, and its nearly circular orbits, would be exceptional.

He attributes the observed high eccentricity of orbit to the influence of tidal friction, and accordingly the greater part of the paper is devoted to the consideration of the results which will ensue from the supposition that each of two bodies raises in the other tidal disturbances, which are subject to frictional resistance.

If the rotations of the two bodies differ in speed, the problem is an insoluble one, without some postulate as to the law of the frictional resistance. The author is, however, of opinion that sufficient insight may be gained from the solution in the case where two equal bodies rotate with equal speed. This opinion seems justifiable, but it might have been well if the dynamical stability of equality of rotations had been explicitly pointed out. That there is such stability is clear from the consideration that, if one of the bodies rotates more rapidly than the other, it is subjected to a more rapid retardation of rotation, and there is accordingly a tendency towards the restoration of equality.

The influence of tidal friction on the elements of the orbit of a satellite and on the rotation and obliquity of a planet have been investigated in my several papers, and Mr. See here adapts my conclusions to the case of the double tidal friction of two stars. The adaptation is not difficult, for whilst the rate of change in the rotation of each star remains the same as though the other did not rotate, the rates of change of the elements of the orbit are exactly doubled. Mr. See has then redrawn the curves which exhibit the gradual transformation of the system, and, as might have been expected, finds them to have features closely similar to those of my curves.

The generality of these solutions is limited by the supposed smallness of the eccentricity and of the inclinations of the orbit and of the two equators to the plane of reference. The author, however, then passes to a second case, which is more special in that the equators of the stars remain coincident with the plane of the orbit, but which is more general in that the eccentricity is not treated as being necessarily small. The object is to obtain a numerical solution of the following problem:—Two equal stars, each of three times the sun's mass, revolve in a nearly circular orbit at a distance equal to that of Neptune from the sun, and the rotation of each star is nearly equal to its orbital motion; it is required to find the greatest mean distance and the greatest eccentricity of orbit to which the system will change under the influence of tidal friction.

Mr. See solves this problem by methods analogous to those which I have employed, and finds that the mean distance will increase from 30 (Neptune's distance) to 50, and that the eccentricity will increase from an assumed initial value of one-tenth to a maximum of about three-fifths, which is attained a little earlier than the maximum of mean distance.

It may be remarked that these results can only be very rough approximations to the truth, because the calculation is conducted on the supposition that the moment of inertia of each star is the same as that of a homogeneous sphere of the same mass and radius, whereas it is obvious that the stars would really be highly condensed spheroids of great oblateness.

It is to be regretted that the calculation has not been repeated with variations of the assumed initial conditions. It is easy to see that a change in the assumed degree of concentration of the stars would give very different results. Supposing, for example, the stars had had only half the diameter assumed, the rotational moment of momentum would have had a quarter of its value in Mr. See's example. Now the enlargement of orbit is due to the transference of rotational to orbital moment of momentum, and thus the transferable moment of momentum would only have amounted to one quarter of its former value. But the orbital moment of momentum varies as the square root of the mean distance, and hence the enlargement of the orbit could not have been so much as one-sixteenth of its former value. We may feel sure that

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the increase in the eccentricity of orbit would also have been largely reduced.

Notwithstanding this criticism, it appears to me that Mr. See fairly establishes the proposition that a high eccentricity is explicable by means of tidal friction.

Turning, then, to the question of the relative masses of the components of double star systems, Mr. See remarks with justice that the comparable brightness of the components renders it highly probable that the masses are also comparable, and he sees in certain results of M. Poincaré and of my own an evolutionary explanation of this fact.

Jacobi first showed than an ellipsoid of homogeneous fluid, with its three axes bearing to one another proper proportions, is a figure of equilibrium when it rotates about its smallest axis with a proper angular velocity. M. Poincaré next showed that if the length of the Jacobian ellipsoid exceeds the breadth in a certain ratio, the equilibrium becomes unstable, but that there is a stable figure which may be described as a Jacobian ellipsoid with a furrow nearly round the middle, so that it resembles an hour-glass with unequal bulbs. If we trace the further development of the hour-glass we find its neck gradually thinning, and finally rupturing the figure of equilibrium, henceforth consists of two detached masses.

My own attack on this problem was from the opposite point of view, for I endeavoured to trace the coalescence of a pair of detached masses so as to form an hour-glass or dumb-bell.

Mr. See reproduces the figures illustrative of both these investigations, and remarks that they both show that when there is a gradual detachment from a rotating figure of equilibrium, the detached portion will not normally be a ring, but that there will ensue two quasi-spheroidal masses of matter of comparable magnitude. He also remarks that if the fluid be heterogeneous, the ratio of the masses will be much smaller than when it is homogeneous.

In the discussion of these figures of equilibrium the wording of the essay appears a little careless, for it might naturally be supposed to mean that increase of angular velocity is a necessary concomitant of the rupture of the neck of the hour-glass. Now it is a somewhat paradoxical fact that, with constant density, the longer elongated figures of equilibrium rotate more slowly than the shorter ones, and it might therefore seem that the rupture of the neck should go with retardation of angular velocity. But it is the value of the square of the angular velocity divided by the density which determines the length of the elongated figures, and thus increase of density tells in the same way as retardation of angular velocity. In the history of a nebula the only condition for rupture which can be specified is that of contraction.

The probability of this view of the genesis of double stars is strikingly illustrated by a number of drawings by Sir John Herschel of various nebulæ. The great similarity between Herschel's nebulæ and the theoretical hour-glass is obvious. It may be hoped that in the book which Mr. See promises he will also illustrate this point by photographs.

Annulation is usually accepted as the mode of separation in the nebular hypothesis, but, as already stated, this is held by Mr. See to be exceptional. He thus regards the ring of Saturn as being as exceptional in its history as it now is in appearance. Where he maintains that Saturn's ring will never coalesce into a satellite, he might with advantage have referred to the remarkable investigations of M. Roche,[1] who showed that a satellite would be torn to pieces by tidal action if it revolved at a distance of less than 2·44 times the planet's radius. We may here note the interesting fact that whilst Saturn's ring almost touches "Roche's limit" on the inside, the Martian satellite, Phobus, and the fifth satellite of Jupiter[2] almost touch it on the outside.[3]

In order to prove his thesis as to the highness of the eccentricity and the comparability of masses, Mr. See gives a careful table of the observed elements of the orbits and of the relative brightnesses of seventy-three pairs of double stars. The values of the elements are of course open to much uncertainty, but the mean eccentricity, which is found to be ·45, must lie near the truth. In the few cases in which the masses have been determined, they are found to be comparable, and the comparability of the brightnesses confirms the generality of this law. Thus the facts of observation agree with our author's ideas.

Mr. See must be congratulated on having written an essay of great cosmogonical interest, and although his theory may never be susceptible of exact proof, yet there is sufficient probability of his correctness to inspire us with fresh interest in the observations of double stars.

G. H. Darwin.

MAGNETIC INDUCTION IN IRON AND OTHER METALS.

Magnetic Induction in Iron and other Metals. By J. A. Ewing, F.R.S. (London: *Electrician* Office.)

In this admirable book Prof. Ewing has brought together matter which was before to be found only in the journals of learned societies, and he has also given a full account of his own researches in magnetism. The book is written in a lucid style, and is supplied with numerous references to original papers.

In Chapter I. Prof. Ewing explains clearly the meaning of such terms as "intensity of magnetisation" and the like, which many students have difficulty in understanding. As stated in the preface, he has "endeavoured to familiarise the student with the notion of intensity of magnetisation (I) as well as with the notion of magnetic induction (B)." When endless magnetic circuits are discussed, it is convenient to talk of "permeability" and "induction"; on the other hand, "magnetic poles" and "magnetisation" are just as important when permanent magnets are dealt with. The magnetisation of ellipsoids and the influence of the shape and dimensions of magnetised bodies upon magnetic quality are fully treated.

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[1] "Acad. des Sciences de Montpelier," vol. i. (1847–50), p. 243. See also Darwin, *Harper's Magazine*, June, 1889.

[2] The values given by Barnard (Nature, p. 377) make the distance 112,000 miles, and Roche's limit 107,000 miles.

[3] It is proper to warn the reader that Roche's limit depends to some extent on the density of the planet. For the sun it will be about one-tenth of the earth's distance from the sun. Thus a body of planetary size cannot move in a highly eccentric orbit, so that its perihelion distance is one-tenth, without being broken up into meteorites; and conversely a flight of meteorites with less than the same perihilion distance can never coalesce into a planet.

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